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Review on Sustainability through Green Chemistry

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ABSTRACT

Each and every facet of our life is related with chemicals and substances. Chemistry is the root of all process. But increased utilization of non degradable toxic chemicals has led to degradation of the environment and is also posing serious affects on human health. Thus, Green chemistry which is the use of chemistry for pollution prevention is the new area of interest for the researchers. The main goals and applications of green chemistry are to reduce environmental, human health and safety risks of chemicals by redesigning the molecules, their synthetic routes, and their development processes. The paper explores the drivers behind the green and sustainable chemistry and the major techniques available for application to sustainable concepts. The present paper highlights the major principles of green chemistry aiming at the sustainable development of materials and presents the major innovations carried so far in the related field.

Keywords: Eco-friendly, green materials, synthesis, sustainability

INTRODUCTION

Development refers to meeting the needs of present generation without compromising the ability of the future to fulfill their own needs. Green chemistry focus on the development of materials and processes which has minimal negative effect on nature. Green chemistry is an interdisciplinary field incorporating chemistry, chemical engineering and ecology. Green Chemistry is the universally acknowledged term to describe environmentally acceptable chemical processes and products[1]. It encompasses education, research, and commercial application across the entire production, processing and supply chain for chemicals[2,3].

The United States Environmental Protection Agency (US EPA) coined the term “Green Chemistry” in the 1990s. Green Chemistry has been promoted worldwide by dedicated individuals and through the activities of some key organizations which include the Green Chemistry Network (GCN) established in the UK in 1998[4] and the Green Chemistry Institute established in the USA in the mid 1990s, now part of the American Chemical Society[5].

The major research efforts in green chemistry may be divided into four major categories of alternative starting materials, transformations, reaction conditions and final product [6-8]. According to the work carried out by Paul T. Anastas[1], the following basic principles of green chemistry have been formulated,

1. Prevention of waste generation rather than post treatment or clean up of waste after it is formed.
2. Atom economy where synthetic methods should be designed in such a way that it incorporates all materials used, into the final product.
3. Synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. Chemicals and chemical products should be designed with reduced or no toxicity.
5. Safer solvents and separation agents with no offensive effect should be promoted.
6. Design of synthetic methods should be done such that they can be conducted at ambient temperature and pressure minimizing environmental and economic impacts and increasing energy efficiency.
7. Use of renewable feedstock to be encouraged wherever possible.
8. Avoiding unnecessary derivatization (blocking group, protection or de-protection, and temporary modification of physical or chemical processes), whenever possible.
9. Catalytic reagents which are selective in nature are better reagents than stoichiometric reagents and hence can be safely used.
10. Design for degradation: Chemical products should be designed so that they do not persist in the environment and break down into harmless degradation products.
11. Real time analysis of analytical methodologies for pollution monitoring and control to be encouraged. This green chemistry principle directly contributes to the safe and efficient operation of chemical plants worldwide.
12. Substances and the form of a substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires.

Literature review

Based on the above principles several methods have been developed and are under investigation which aim at cost effective and eco-friendly product development.

Catalysis plays a significant role in green chemistry approach. Catalysis is either homogenous catalysis, when the catalyst is in the same phase as the reaction mixture or heterogeneous catalysis, when the catalyst is in a different phase. Zeolites, solid acids, micelle-templated silicas and other mesoporous high surface area support materials have a significant role in the greening of chemicals manufacturing processes. Environmentally benign solid acid catalysts such as SO42- /ZrO2, SO42- / TiO2, Ce-exchanged montmorillonite, and siliceous mesoporous material have been reported to be active for the acetylization reactions[9-12]. Epling and coworkers carried out cleavage of dithiane and oxathiane ring systems instead of toxic heavy metal catalysis reduction process offering important transformations useful in pharmaceutical industries.

Microwave technology can be used in some reactions to provide the heat energy required to make the transformation go to completion. By using Microwave technology, significantly shorter reaction times than normal has been obtained for organic transformations like esterification, hydrolysis, etherification, addition, and rearrangement reactions. Li and co-workers reported the microwave-assisted coupling of phenols with high to excellent yields within 10 min.[13]. Microwave induced synthesis of thioketones, thiolactones, thioamides, thionoesters by using carbonyl compounds with 0.5 equiv. of Lawesson's reagent was successfully demonstrated by R. S. Varma[14].

Considering the harmful effects of conventionally used solvents researchers are in constant exploration of their green alternatives. The main alternatives include super critical fluids (supercritical CO2 and CO2/H2O), aqueous solvents, immobilized solvents (Tetrahydrofuran (THF) attached to polymeric backbone), ionic liquids etc. In one of the research carried out by Eckert and Liotta Friedel-Crafts reactions was performed in near –critical water without the need for the acid catalyst AlCl3 thus making the process not only cost effective but also ecofriendly. In recent years, there has been increasing recognition that water is an attractive medium for many organic reactions due to its cost effectiveness, zero toxicity and environment friendly aspect. Li et al. have successfully employed an indium catalyst in a number of carbon–carbon bond forming reactions conducted in aqueous mediated process[15].

Use of biocatalysis in biochemical reactions, synthesis of bioactive molecules and in biotechnology due to their selectivity, sustainability and environmental safety holds a promising feature in developing novel pathway for production of chemical compounds.

In view to develop reaction methodology to reduce waste, initiates generation of chemicals from reagents in the absence of hazardous and expensive solvents[16]. Recently solvent-free reaction has attracted researchers due to related lower expenses and easier procedures. Zirconium chloride was described to be a new and highly competent catalyst which catalyzed aldol reaction of appropriately substituted aromatic aldehydes and ketones to get the corresponding 1, 3-diaryl-2-propenones[17-19] in short span of time without the formation of side product at room temperature in solvent free conditions. Similarly, strong methylating agents like dimethyl sulphate can be replaced by dimethyl carbamate for methylation of acrylonitriles and methylacrylates thereby eliminating the toxic effect of dimethyl sulphate. Ludwig and coworkers developed first commercial process for scavenging hydrochloric acid using ionic liquid 1-methylimidazole instead of triethylamine which would have otherwise generated ammonium salt leading to slurry formation which requires cost intensive elimination methods [20]. Attempts have been made to mask the toxic functional group to a non toxic derivative form. For eg. Harmful effects of vinyl sulfones can be masked by synthesizing a relatively less hazardous hydoxyethylsulphone.

New synthetic pathways have been reported for the manufacture of adipic acid using glucose as starting material than traditionally used benzene which is carcinogenic. R. A. Sheldon[21] critically reviewed various strategies for the valorisation of waste biomass to platform chemicals. In another approach Song and coworkers[22] highlighted the conversion of glucose and cellulose into value-added products in water and ionic liquids contributing to sustainable chemistry. Synthesis and mechanistic studies of urethanes from amines, CO2, and alkyl chlorides was carried out using carbon dioxide as a replacement for hazardous phosgene. In one such attempt, o-sulphobenzoic acid anhydride was successfully used as dehydrating agent having the advantage of selective conversion of amines and carbon dioxide into their corresponding isocyanates but also having the recycling potential thereby reducing generation of salt waste. The production of dye indigo is fruitfully carried out by using green route where enzymatic oxidation of indole to indigo occurs which is environmentally benign. Newer enzymatic process of conversion of glucose is more promising as it is eco-friendly.

Researchers have successfully produced chemical products from natural materials like palm, coconut, palm seeds, soy oils etc. which can be employed in industries, pharmaceutical and body care. A number of attempts are under investigation which can be efficient contributor to eco-friendly approach of chemistry[23-24]. Designing of the chemicals are in process keeping the aim of atom economy (100% utilization), non-toxicity and no bioaccumulation. The work so far is an inspiration for future researchers to generate scientific innovations in green chemistry.

CONCLUSION

The idea of green chemistry is expanding its wings from laboratories to industrial application with the aim of reduced cost, less health risk and eco-friendly nature of substances. A number of process have been successfully developed which poses no ill effect on human health and environment. But the concept is not widely implemented due to requirement of specialized knowledge and acceptance in business decisions. The bridge between the theory and the applicative part of green chemistry can be removed if the concept is willingly adopted into industries with proper federal policies and education. Thus, the growth of green chemistry can lead to development, profits, and protecting our planet.

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